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Original Article

STUDY OF TEXTURAL BEHAVIOR OF CONCRETE PAVEMENT: A CASE STUDY OF YAMUNA EXPRESSWAY

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ABSTRACT

In the modern world, transportation has reached a new level with enhanced technology and innovative material for construction. Modern time requires higher speed and lesser time of travel between origin and destination, hence expressways have attained more priority than the other category of road. They have a design module of lesser intersections, lesser obstruction, hence providing higher speeds even >100 kmph. The rigid pavement design of the expressways has given higher speed but has somehow compromised in the surface friction part too and to balance this part, there has been a provision of higher texture depths which has given better griping value both in dry and wet conditions. But now it has come into notice that there is a tire bursting phenomenon that is occurring in the rigid pavement, hence this paper has analysed the amount of energy that is contributed by the higher texture depths into the rolling tires. This paper tries to make a study of the energy produced when a tire rolls on the surface of rigid pavement and how it gets distributed into the atmosphere and some absorbed by the rolling tire. This paper will more give emphasis on the portion of the energy produced because of the textures provided on the pavement; and will not include the loss of energy due to any other cause. Texture provided on the pavement is basically a series of repeating figures drawn transverse to the moving direction in order to attain a desired value of skid resistance and friction so as to avoid skidding in any condition. But in view of this, there is an abrupt increase in the amount of energy being produced and this is causing the problem of tire bursting. So for the analysis tests were conducted at the site and the initial and the final pressure of the tires were noted down. The kinetic theory of gases has given the kinetic energy of the enclosed gas before the test and after the test. Since there is an increase in the pressure of the tires hence using Gay Lussac's law we concluded there will be an increase in the temperature also hence final temperature was calculated. The increase in the kinetic energy gave us the conclusion about the mean texture depth that can be adopted. For a minimum case, it was concluded that the texture depth of about <1.8-1.9 mm is optimum considering the energy increase within the tires. For the test site, it was concluded that texture depth>2.75mmisnot suitable though providing high amount of resistance hence causing tire burst accidents. Therefore it was concluded that the ideal texture depth for the site would be recommended to be < 2.75 mm for future activity of maintenance. Friction analysis and the contact area patch analysis has also given the reasons why low inflation pressure and the poor quality of the tires can lead to the tire bursting phenomenon. There has not been a lot of research going on regarding this issue but research papers related to a few key problems involved in this study on combining will pave the foundation for the advance of research on this issue.

KEYWORDS: Yamuna Expressway; Textural; Concrete Pavement & Transportation

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1. INTRODUCTION

Two types of pavements are laid in India-rigid pavement and flexible pavement. In simple terms, a flexible

pavement can be defined as a pavement layer comprising of a mixture of aggregates and bitumen, heated and mixed properly and then laid and compacted on a bed of granular layer. Rigid pavements, on the other hand, are made from cement concrete or reinforced concrete slabs, laid over a low strength concrete layer (Dry lean concrete, DLC) or on a well-compacted layer of aggregates or both. Till now, flexible pavement has been preferred over rigid pavement due to the low initial costs. However, with the increasing availability of cement in the country coupled with the rising prices of bitumen, the government's decision to opt for rigid pavement is being perceived as a prudent one. Raw material for the cement industry is limestone which is available in abundance in India and no foreign currency is required. The main ingredient of flexible pavement mix is bitumen which is a by-product of refinery. Raw material for refinery is crude oil, the majority of which have been imported from oil exporting countries and no huge amounts of foreign currency are required.

The decision of rigid pavement, taken after considering factors related to service life, fuel consumption, weather conditions, maintenance costs and natural resources, primarily aims to promote environment friendly construction practices in the execution of road projects.

The initial cost of rigid pavement is no doubt higher than that of flexible pavement. In terms of lifecycle costing, however, rigid pavement has proved to be more economical than flexible pavement.

Rigid pavement is generally preferred for locations experiencing heavy rainfall, waterlogged areas and areas having sub-grade soil with low CBR (California Bearing Ratio) values.

The stability of the roadway surface is a very important aspect in the design of the pavement and should be non-yielding to allow the heavy wheel loads of traffic to move with minimum possible rolling resistance. The surface of the road should also be uniform along with the longitudinal profile so as to provide the fast moving vehicles to move safely and comfortably at the design speed. The main objective of a well designed and constructed pavement is to have elastic deformation within the permissible limits so that the roadway can sustain a large number of repeated load applications during its design life.

1.2 Bursting of Tires

This is one of the common causes of accidents that have been occurring in the major highway and expressway systems. Broadly bursting of a tyre occurs when there is a rapid loss of pressurized air from within the tyre. When there is a compromise with respect to the structural integrity of the tire, the tire is unable to hold all that air inside. Due to this situation, the pressurized air escapes out tearing apart the tyre and rapidly causing an explosion and severe damage to the tyre surface. The major causes of the tyre burst are listed below:

1.2.1 Direct Impact

Due to the poor condition of the pavement surface, there is a high possibility of a direct impact of the tyre resulting in slashing of the tyre surface at some point which becomes an open invitation for all the pressurized air to escape out thus leading to tyre burst.

1.2.2 High Temperature

Since most of India lies in the tropical or a subtropical region so it is prone to hot weather resulting in high temperatures and in general heat is the enemy for different parts of the vehicle especially the tyre. Due to high temperature, there is an excessive build-up of heat in the tyres and this increase in temperature inside the moving tyre results in an increase in the

pressure within the tyre. The friction between the pavement surface and the moving tyre helps this process and weakens the tyre which may result in bursting of tires due to this heat build-up.

1.2.3 Under Inflation

Another one of the major causes of the bursting of the tyres, Over inflation is not of a major concern under inflation is the reason behind more than 75 % of tyre burst induced accidents. Such under inflation tyres suffer from excessive flexing and that increases the contact patch with the pavement surface which leads to the accumulation of excessive frictional force and in turn builds up the heat inside the tyre. The building up of heat is much higher than those induced during the hot summer.

1.2.4 High Speed

Every tyre is meant to function best at a particular speed and there is a maximum speed that the tyre can hold. Beyond the particular speed will increase the friction levels and wear quickly, so in this case, more than one factors are responsible for the bursting of tires.

1.2.5 Concrete pavement have two engineering parameters that govern the movement of vehicles on the road.

1.2.5.1 Skiding

Accidents occur on concrete pavement due to the smoothness of the travelling surface. The rear vehicle collides front vehicle especially in the wet season when a brake is applied and water over the surface acts as a lubricant between the wheel and pavement surface. To make pavement surface skid resistance, textures are provided over the surface. Though travelling surface becomes skid resistance by providing texturing and accident has been avoided.

1.2.5.2 Energy Produced

Huge quantities of extra energy are produced due to texturing on the surface in form of heat. A major part of the heat is diffused in the environment which causes some environmental impact. Some parts of heat are transmitted inside the tire through the wheel of the vehicle and increased temperature of the air inside the tire. The increase in temperature in tire increases the pressure of air inside the tire. Finally, tire bursts causes a vital accident when travelling time is more.

Yamuna Expressway

Yamuna expressway also known as Taj Expressway is basically a 6 lane, extendable to 8 lanes, 165 km long access-controlled expressway which connects Greater Noida with Agra in the territory of Uttar Pradesh. It is one of India's longest six-lane expressways. This expressway starts from Pari Chowk in Greater Noida and ends at Kuberpur in Agra. It is monitored and maintained by a body called Yamuna Expressway Industrial Development Authority (YEIDA).

Figure 1

With due permission from the concerned authority, some basic technical features of the expressway were obtained. Below is the table of features of the Expressway:

Table 1

S. no.	Description	
1.	Total number of lanes	6: 3.5 m width each
2.	Permissible speed	100 kmph for LMV 60 kmph for HMV
3.	Maximum Allowable speed	120 kmph
4.	Total length	165.5 km
5.	Right of Way	100 m wide
6.	Pavement Width	15.70 m
7.	Maximum axle load design	20 tonnes
8.	Shoulder Width	5.10 m
9.	Thickness of PQC	320 mm (main carriageway)
10.	Thickness of DLC	150 mm
11.	Top Width of Embankment	47.60 m (including 6.0 m wide Median)
12.	Vehicle underpass	70
13.	Minor bridges	41
14.	Interchanges	6
15.	Box Culverts	182
16.	Main Toll Plaza	3 (26 lanes at each location)
17.	Concrete	33.2 lakh cum
18.	Cement	12.0 lakh tonnes
19.	Steel	1.30 lakh tonnes
20.	Stone Aggregate	130 lakh tonnes
21.	Bitumen	7500 tonnes
22.	Admixtures	12500 tonnes

Measurement of Texture

Table 2

SN	Chainage	Distance from base line	Greater Noida to Etmadpur			Etmadpur to Greater Noida		
			Texture depth in mm			Texture depth in mm		
			Right	Center	Left	Right	Center	Left
1.	14.400	0	4	3	3	4	3	3
		12	3	2	4	3	3	2
		16	3	3	3	3	3	2
		14	5	4	3	4	2	4
		16	3	2	4	2	4	3
		13	4	3	3	3	3	4
		15	2	3	4	3	2	3
		17	3	3	2	4	4	4
		11	3	4	3	3	3	3
		16	3	4	3	3	3	2
		13	2	3	4	2	3	4
		14	4	2	4	4	4	3
		15	3	3	3	3	2	2
		14	2	3	4	2	3	3
		12	3	3	3	4	3	4
2.	31.200	0	3	3	3	4	3	3
		12	3	3	4	3	3	2
		16	2	3	3	3	3	4
		14	4	4	3	3	3	3
		16	3	4	3	3	4	3
		13	4	3	4	3	3	4
		15	3	3	3	4	3	3
		17	3	3	2	4	4	4
		11	3	3	4	3	4	3
		16	3	3	3	3	3	3
		13	4	3	4	4	3	3
		14	3	3	3	4	4	3
		15	3	4	3	4	3	3
		14	2	3	3	2	3	3
		12	3	3	4	3	3	3
3.	45.800	0	3	3	3	4	3	4
		12	4	3	4	3	3	2
		16	3	3	4	3	3	4
		14	4	4	3	3	2	4
		16	4	2	4	2	3	3
		13	3	3	4	3	2	4
		15	3	3	4	3	4	3
		17	3	3	2	3	4	3
		11	3	3	3	3	4	3
		16	3	4	3	4	3	3
		13	3	3	4	2	3	3
		14	4	2	4	4	4	3
		15	4	3	3	3	3	2
		14	2	3	3	2	3	3
		12	3	2	3	4	3	2
4.	71.800	0	3	3	3	4	3	3
		12	3	3	4	3	3	2
		16	3	3	4	3	3	2
		14	4	4	3	4	2	4

		16	3	2	4	3	4	3
		13	3	3	3	4	3	4
		15	2	3	4	3	2	2
		17	3	3	2	4	3	4
		11	3	4	3	3	2	3
		16	3	4	3	4	3	2
		13	2	3	3	2	3	4
		14	4	2	3	4	3	3
		15	3	3	3	3	2	2
		14	4	3	4	2	4	3
		12	3	3	3	4	3	3
5.	87.200	0	2	3	3	4	2	3
		12	3	2	4	3	3	3
		16	3	4	3	3	3	2
		14	5	3	3	4	2	4
		16	3	2	4	3	4	3
		13	4	3	2	3	3	4
		15	2	3	4	3	3	3
		17	3	3	2	3	4	4
		11	3	0	3	3	3	3
		16	3	4	3	3	3	3
		13	2	3	4	2	3	3
		14	4	2	3	4	4	3
		15	3	3	2	3	2	2
		14	2	3	4	3	3	3
		12	3	3	3	4	3	2
6.	108.000	0	4	3	3	4	3	3
		12	3	2	4	3	3	3
		16	3	3	3	4	3	2
		14	5	3	3	4	2	4
		16	3	0	4	2	4	3
		13	3	3	3	3	3	4
		15	2	3	4	3	3	3
		17	3	3	2	4	3	4
		11	3	4	3	4	3	3
		16	3	4	3	3	2	2
		13	2	3	4	2	0	4
		14	4	2	4	3	4	3
		15	3	3	2	3	2	2
		14	2	3	3	2	3	3
		12	3	3	3	4	3	4
7.	134.600	0	4	3	3	3	3	3
		12	3	2	3	3	3	2
		16	3	1	3	3	3	2
		14	3	4	3	3	2	4
		16	3	2	4	2	3	3
		13	4	3	3	3	3	3
		15	2	3	1	3	2	3
		17	3	3	2	3	4	4
		11	3	4	3	3	2	3
		16	3	4	3	2	3	2
		13	2	3	4	2	3	3
		14	4	2	4	3	4	3
		15	3	3	2	3	2	2
		14	2	3	4	2	2	3
		12	3	3	3	3	3	4

8.	147.400	0	4	3	3	4	0	3
		12	3	2	1	3	3	2
		16	3	3	3	2	3	2
		14	5	2	3	4	2	4
		16	3	2	3	2	4	3
		13	4	3	3	4	3	4
		15	2	3	4	2	2	3
		17	3	3	2	4	2	4
		11	3	4	3	4	3	3
		16	3	4	3	3	3	2
		13	2	3	4	2	3	2
		14	4	2	4	2	4	3
		15	3	2	3	3	2	2
		14	2	3	2	2	3	2
		12	3	3	3	2	3	4
9.	162.200	0	3	3	3	4	3	3
		12	3	2	4	3	3	2
		16	3	1	3	2	3	2
		14	5	3	3	4	2	4
		16	3	2	4	2	3	3
		13	4	3	2	3	3	3
		15	2	1	4	3	0	3
		17	3	3	2	4	4	4
		11	3	1	3	2	3	3
		16	3	4	3	3	2	2
		13	2	3	2	2	3	4
		14	4	2	2	4	3	3
		15	3	2	3	3	3	2
		14	2	3	4	3	2	3
		12	3	2	3	4	3	3

Measurement of Pressure

Date – 23/05/2021

Day time Temperature – 38 0

Table 3

Sn	Tyre Company	Journey Start Time	Journey Finish Time	Average Speed	Type of Vehicle	Front Axle	Rear Axle	Initial Tyre Pressure						Final Tyre Pressure					
								Front axle		Rear axle				Front axle		Rear axle			
								Right	Left	Right inner	Right outer	Left inner	Left outer	Right	Left	Right inner	Right outer	Left inner	Left outer
1	Appolo	10.30	12.20	90	car	1	1	33	34	34	33	33	33	48	47	44	45	42	44
2	Appolo	10.35	12.25	82.5	jeep	1	1	32	35	33	33	33	34	46	44	45	46	44	45
3	Appolo	10.40	12.55	73.33	Mini Truck	1	1	34	36	34	33	33	32	45	48	48	46	45	44
4	Appolo	10.45	12.45	82.5	Truck	1	1	36	32	35	34	32	33	43	44	47	45	46	46

Measurement of Pressure

Date – 24/05/2021

Day time Temperature – 36 0

Table 4

S. n	Tyre company	Journey start time	Journey finish time	Average Speed	Type of Vehicle	Front Axle	Rear axle	Initial Tyre Pressure						Final Tyre Pressure					
								Front axle		Rear axle				Front axle		Rear axle			
								Right	Left	Right inner	Right outer	Left inner	Left outer	Right	Left	Right inner	Right outer	Left inner	Left outer
1	MRF	10.30	12.20	90	car	1	1	35	33	34	33	33	33	48	47	44	45	44	44
2	MRF	10.35	12.25	82.5	jeep	1	1	32	35	32	33	32	34	46	45	45	46	44	45
3	MRF	10.40	12.55	73.33	Mini Truck	1	1	34	35	34	33	32	32	45	48	48	47	45	45
4	MRF	10.45	12.45	82.5	Truck	1	1	36	33	35	34	33	33	43	44	47	46	46	46

Measurement of Pressure

Date – 25/05/2021

Day time Temperature – 36 0

Table 5

Sn	Tyre company	Journey start time	Journey finish time	Average Speed	Type of vehicle	Front axle	Rear axle	Initial Tyre Pressure						Final Tyre Pressure					
								Front axle		Rear axle				Front axle		Rear axle			
								Right	Left	Right inner	Right outer	Left inner	Left outer	Right	Left	Right inner	Right outer	Left inner	Left outer
1	Good Year	10.30	12.20	90	car	1	1	33	34	34	33	33	33	48	47	44	45	44	44
2	Good Year	10.35	12.25	82.5	jeep	1	1	32	34	33	33	33	34	46	44	45	47	44	45
3	Good Year	10.40	12.55	73.33	Mini Truck	1	1	-	-	-	-	-	-	-	-	-	-	-	-
4	Good Year	10.45	12.45	82.5	Truck	1	1	33	33	35	34	35	33	47	44	47	45	45	46

Measurement of Pressure

Date – 26/05/2021

Day time Temperature – 36 0

Table 6

Sn	Tyre company	Journey start time	Journey finish time	Average Speed	Type of Vehicle	Front axle	Rear axle	Initial Tyre Pressure						Final Tyre Pressure					
								Front axle		Rear axle				Front axle		Rear axle			
								Right	Left	Right inner	Right outer	Left inner	Left outer	Right	Left	Right inner	Right outer	Left inner	Left outer
1	Fire stone	10.30	12.20	90	car	1	1	35	34	32	33	32	33	48	47	44	45	44	44
2	Fire stone	10.35	12.25	82.5	jeep	1	1	33	35	33	34	33	34	46	44	45	47	44	45
3	Fire stone	10.40	12.55	73.33	Mini Truck	1	1	34	35	34	33	33	33	45	48	47	46	45	46
4	Fire stone	10.45	12.45	82.5	Truck	1	1	36	33	35	34	32	33	43	46	47	45	46	47

Measurement of Pressure

Date – 24/05/2021

Day time Temperature – 36 0

Table 7

s.n	tyre company	journey start time	journey finish time	average speed	type of vehicle	front axle	rear axle	Initial Tyre Pressure						Final Tyre Pressure					
								Front axle		Rear axle				Front axle		Rear axle			
								Right	Left	Right inner	Right outer	Left inner	Left outer	Right	Left	Right inner	Right outer	Left inner	Left outer
1	Fire stone	10.30	12.20	90	car	1	1	35	34	32	33	32	33	48	47	44	45	44	44
2	Fire stone	10.35	12.25	82.5	jeep	1	1	33	35	33	34	33	34	46	44	45	47	44	45
3	Fire stone	10.40	12.55	73.33	Mini Truck	1	1	34	35	34	33	33	33	45	48	47	46	45	46
4	Fire stone	10.45	12.45	82.5	Truck	1	1	36	33	35	34	32	33	43	46	47	45	46	47

Statement of Road Accidents

Table 8

Sn	Month	Road Accidents				Number of Fatal Casualties				Number of Injuries			
		2016	2017	2018	2019	2016	2017	2018	2019	2016	2017	2018	2019
1	Jan	77	82	37	39	11	11	4	16	162	132	74	72
2	Feb	75	72	32	40	6	10	4	22	64	94	87	76
3	Mar	91	90	39	56	12	11	11	16	112	143	97	132
4	Apr	129	68	54	44	3	19	11	8	151	150	132	142
5	May	102	60	94	57	10	16	7	10	161	111	140	146
6	Jun	108	60	85	64	16	11	10	33	126	120	202	120
7	Jul	131	53	62	57	10	13	19	40	156	95	136	134
8	Aug	110	54	44	25	17	5	7	13	116	111	99	60
9	Sep	84	40	49	42	8	11	5	10	102	74	97	100
10	Oct	118	64	59	50	12	13	7	10	105	132	138	106
11	Nov	98	58	61	42	9	11	11	5	141	152	114	114
12	Dec	96	61	43	-	19	15	15	-	129	112	72	
	Total	**1219**	**763**	**659**	**516**	**133**	**146**	**111**	**183**	**1525**	**1426**	**1358**	**1202**

MEASUREMENT OF TYRE PRESSURE

Lucknow Prayagraj Road (Flexible Pavement)

Date – 29/05/2021

Day time Temperature – 36 0

Length covered: 165 km

Table 9

S n	Tyre company	Journey start time	Journey finish time	Average Speed	Type of vehicle	Front axle	Rear axle	Initial Tyre Pressure						Final Tyre Pressure					
								Front axle		Rear axle				Front axle		Rear axle			
								Right	Left	Right inner	Right outer	Left inner	Left outer	Right	Left	Right inner	Right outer	Left inner	Left outer
1	MRF	8.30	10.50	71	car	1	1	32	33	33	34	31	32	39	41	40	40	39	40
4	APPOLLO	8.25	12.10	44	Truck	1	1	31	34	32	33	32	31	38	40	38	39	38	40

MEASUREMENT OF TEXTURE

Lucknow Prayagraj Road (Flexible Pavement)

Date – 29/05/2021

Day time Temperature – 36 0

Length covered: 165 km

Table 10

SN	Chainage	Distance from base Line	Lucknow to Prayagraj		Prayagraj to Lucknow	
			Texture Depth in mm		Texture Depth in mm	
			Right	Left	Right	Left
1	135.400	0	1	1	1	2
		10	2	1	2	2
		20	2	1	2	1
2.	105.200	0	2	2	1	2
		20	1	1	2	2
		40	1	2	1	1

DATA ANALYSIS

This graph has been prepared between the type of pavement and pressure in the tyre after travelling of equal distance of 165 km

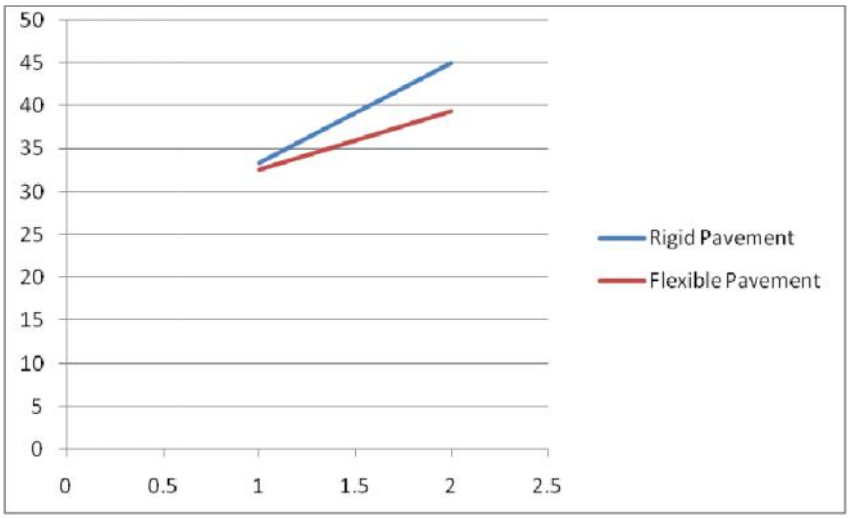

Figure 2

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